Production Capacity Change in Industrial Sectors of Hachinohe City due to the 2011 Tohoku Tsunami

IDRiM (2016) 6 (2) ISSN: 2185-8322
DOI10.5595/idrim.2016.0169

IDRiM FOR A SAFER WORLD Journal of Integrated Disaster Risk Management

Original paper

Production Capacity Change in Industrial Sectors of Hachinohe City due to the 2011 Tohoku Tsunami

Kentaro Kumagai[1]*, Rafael Aránguiz[2], and Kenji Ono[3]

Received: 31/12/2015 / Accepted: 15/11/2016 / Published online: 19/1/2017

Abstract In this study, production capacity change was assessed for an inundation area due to the 2011 Tohoku tsunami. The study area was the coastal area of Hachinohe city, which was damaged and inundated by the earthquake and tsunami. Data for the activities of 10 industrial sectors were assembled from published information, newspaper articles, and public announcements. The results showed that the estimated amount of economic damage was approximately 101.9 billion yen because of the production capacity change in the industrial sectors of the area due to the earthquake and tsunami. The estimated amount was equivalent to approximately 84 % of the amount of the stock damage in the city. Time-series of production capacity rate in tsunami inundated area showed differences and showed slower recovery of production capacity rate from that of the earthquake affected area.

Key words Production capacity change; Industrial sectors; The 2011 Tohoku tsunami.

1. INTRODUCTION

Tsunami inundation causes stock damage such as damage to infrastructure, destruction of industrial plants, deprivation of in-stock items, collapse of residences and other damage. Tsunami fragility curves (TFCs) are available for estimating the fragility of facilities against tsunamis (Mas et al. 2012); it is possible to evaluate stock damage with the proper TFCs, and high-resolution spatial data on the facilities and the tsunami inundation maps in fine-grid mesh.

Tsunamis also cause damage resulting in a decrease of production in industrial sectors and economic losses in commercial sectors. We define these types of damage as 'flow damage'. Although it seems to be true that the industrial sector plays an important role in economic activities, little information is available for analysing flow damage of the industries, because many industries belong to private business activities and detailed economic data on their activity is not open to the public. However, the visible outlines of the

[1]Disaster Prevention Research Institute of Kyoto University, Kyoto, Japan, kumagai.kentaro.3e@kyoto-u.ac.jp
[2]Universidad Católica de la SSma Concepción and National Research Center for Integrated Natural Disaster and Management, Concepción, Chile, raranguiz@ucsc.cl
[3]Disaster Prevention Research Institute of Kyoto University, Kyoto, Japan, ono.kenji.5z@kyoto-u.ac.jp
*Corresponding Author

***IDRiM* (2016) 6 (2)** **ISSN: 2185-8322**
DOI10.5595/idrim.2016.0169

factories can be obtained easily from high-resolution aerial photos, digital maps, or paper maps. And sizes of factories are related to the numbers of employees and the amount of production. Therefore, analysts can estimate flow damage by using these outline data and statistical data.

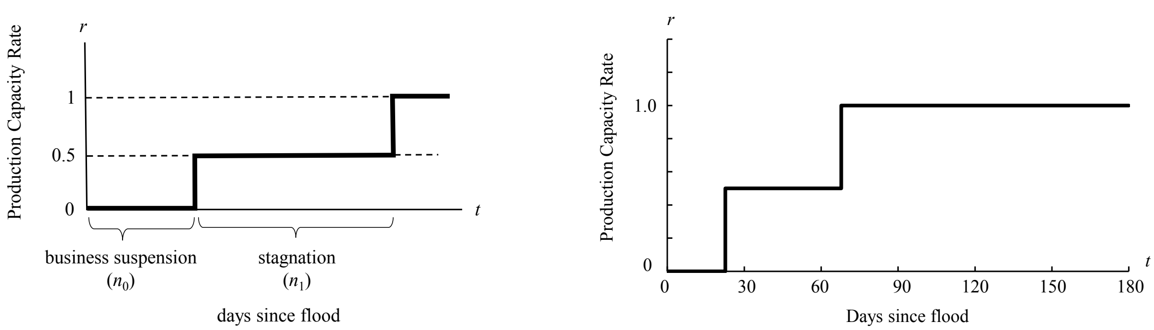
For example, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan published a technical manual that showed a typical method to evaluate the stock and flow damage of floods. The method shown was a simple one that used the constant coefficient of transformation from the number of employees to economic losses per day for the industrial sector in view of the estimated economic losses from business suspension (MLIT 2005). The MLIT manual shows a table of the days of business suspension and the days of stagnation (**Table 1**). The former ranges from a minimum of 3.0 to a maximum of 22.6 days for in the maximum, and the latter ranges from a minimum of 6.0 to a maximum of 45.2 days for in the maximum, depending on the inundation depth of the flood. These results were collected from a questionnaire survey after a flood event. MLIT proposed an equation for damage, D, of business suspension and stagnation:

$$D = M \times (n_0 + \frac{n_1}{2}) \times p \tag{1}$$

where M: the number of labours, n_0: days of business suspension, n_1: days of stagnation, p: added value. The value of p equals to value divided by the number of person and days, in the unit of yen per person and day. In condition that M and p are constant, the equation (1) implies that MLIT modelled production capacity recovery process as shown in **Fig. 1** (1). For example, in case that an inundation depth is greater or equals to 3.00 m, **Fig. 1** (2) is a time-series of production capacity recovery. This method is simple enough, but the constant coefficient may vary depending on the geographical location of the company, the type of industry, conditions of labour market of the area, the degree of technical innovation, and the other factors.

Table 1. Days of business suspension and stagnation
Source: MLIT 2005.

Inundation Depth (m)	below the floor level	above the floor level				
		less than 0.5	0.5-0.99	1.00-1.99	2.00-2.99	greater or equal to 3.00
days of business suspension (= n_0)	3.0	4.4	6.3	10.3	16.8	22.6
days of stagnation (= n_1)	6.0	8.8	12.6	20.6	33.6	45.2



(1) Conceptual diagram (2) Greater or equal to 3.00 m in inundation depth

Fig. 1. Recovery model from flood (Source: MLIT 2005)

The methodology in the previous paragraph was proposed for evaluation of damage due to flood. Kajitani et al. (2013) proposed evaluation method of damage due to earthquake. They used survey data of Nakano et al. (2012) and shows the production capacity changes from the day of the 2011 Tohoku earthquake to 180 days after the disaster. Production capacity of the industrial sector was approximately 0.4 on the day of disaster, approximately 0.9 on 60 days after the disaster, and approximately 0.95 on 180 days after the disaster (**Fig. 2**). The figure was reproduced from Kajitani et al. (2013) by the authors of this manuscript. Black points and dotted line in this figure shows average of manufacturing industries, and the curve line of relation between production capacity on the vertical axis and days after the disaster on the horizontal axis is concave down. This result was collected from the questionnaire survey in Miyagi and Iwate prefecture mainly in areas that were affected by the earthquake, not in the area affected by the tsunami. It appears to be important to conduct a survey and draw lines for production capacity changes in areas that are affected by tsunamis, and it will be useful to know the difference of production capacity change between an earthquake and a tsunami. These results also would be interesting in practical use for decision makers of local governments, disaster risk analysts, and business managers.

The present paper aims to assess the production capacity changes in the industrial sector due to the 2011 Tohoku tsunami. The second chapter describes the industrial sector under analysis and the third chapter assesses the production capacity change. The forth chapter gives a discussion and the fifth chapter presents the main conclusions.

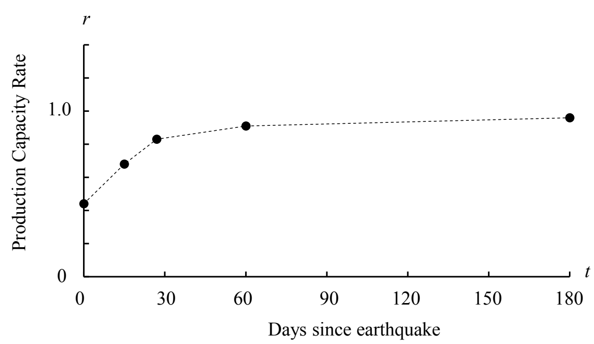


Fig. 2. Recovery model from earthquake (Source: Kajitani et al. 2013)

2. INDUSTRIAL SECTORS AFFECTED BY TSUNAMI

2.1 Industrial Sectors in the Tsunami Inundation Area

Hachinohe city is one of the major industrialized cities in northern Japan. **Fig. 3** shows a location of the city. The maximum tsunami height was approximately 6-8 m in the city (The 2011 Tohoku Earthquake Tsunami Joint Survey Group 2012).

First, the authors digitized the maximum inundation area map of the 2011 Tohoku tsunami in Hachinohe city (Haraguchi and Iwamatsu 2011) into a shape-type file using ArcMap Ver. 10.3 (ESRI Japan Corporation), Geographic Information System (GIS) software. The digital map data for the building shapes, including industrial factories and residences, was input from Z MAP TOWN II CD-ROM (Zenrin Co., Ltd.) to the GIS software. By overlapping the inundation map on the building shape map (**Fig. 4**), the authors picked up large size buildings, i.e. a floor area of more than 1,000 m^2 on the first floor, in the tsunami inundation area. The number of the buildings were 283, and the floor area was 858,880 m^2 in total.

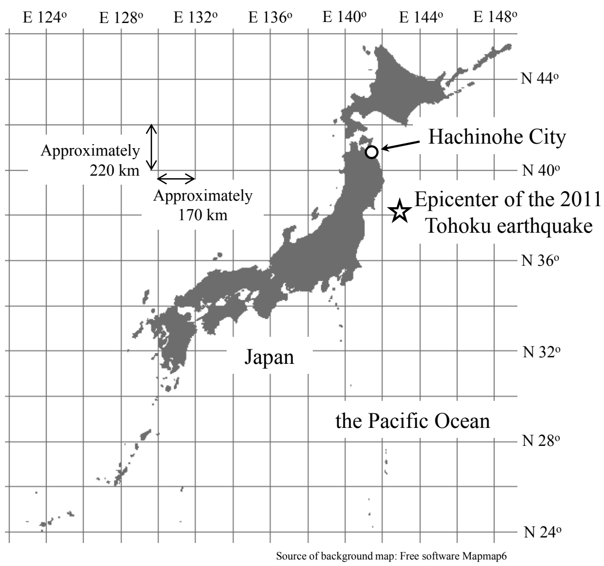


Fig. 3. Location of Hachinohe City

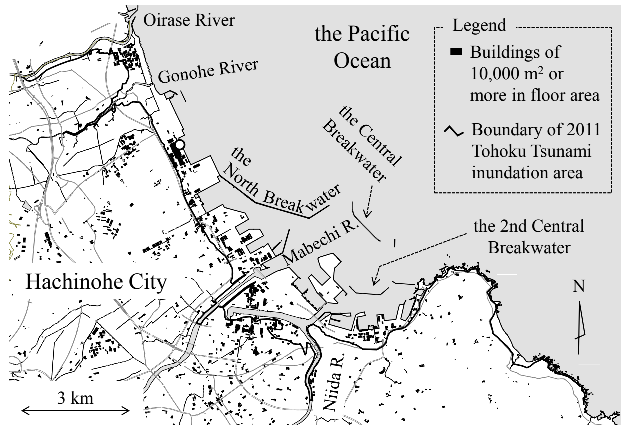


Fig. 4. Inundation area and buildings

The building shape map includes not only the building shapes, but also the company names of the building tenants. Using the latter information and 'the street view' function of Google Earth Ver. 7.15.1557, provided by Google Inc., the authors identified company names for most of the buildings; however, for 53 buildings, the company names were unclear. Finally, the authors matched 230 buildings to company names, a total of 748,171 m^2 in floor area (**Fig. 5**).

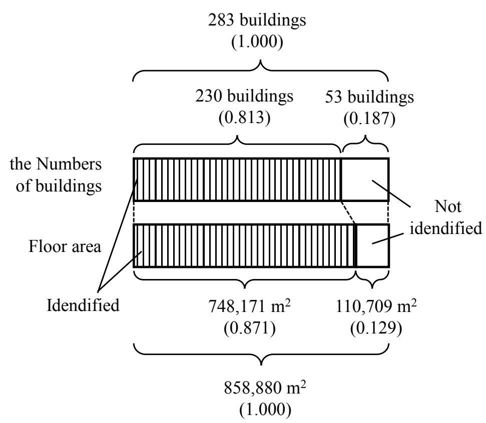


Fig. 5. Identification of company names

The Ministry of Internal Affairs and Communications of Japan (MIC 2013) provides a table called *the Standard Industrial Classification* of all economic activities (SIC, Rev. 13). The MIC categorize all of Japan's economic activities into 99 sectors identified by SIC code 1-99, and the sector name. The authors assigned the SIC code to the 230 buildings on the basis of the company name.

Because the SIC targets all economic activities, it includes both the industrial (SIC code: 09-32) and the non-industrial (SIC code: 01-08 and 33-99) sectors (**Table 2**). From the 230 buildings, the authors identified 155 to be in the industrial sectors, SIC code 09-32. Many industrial companies had multiple

IDRiM (2016) 6 (2) ISSN: 2185-8322
DOI10.5595/idrim.2016.0169

buildings in the target area, so the authors integrated the buildings into one column and summed the values of the building floor areas into one value.

Finally, the authors produced a list of 60 companies of the industrial sectors in the Hachinohe city inundation area due to the 2011 Tohoku tsunami, with their SIC codes. The total floor area is 543,611 m^2, equivalent to 63 % of the floor area of all buildings, 858,880 m^2. The 60 companies are categorized into ten industrial sectors, as shown in **Fig. 6**.

Table 2. SIC codes (Source: MIC 2013)

(1) Major classification

SIC code	Name of Sector
1 - 2	Agriculture and Forestry
3 - 4	Fishery
5	Mining and Quarrying of Stone
6 - 8	Construction
9 - 32	Manufacturing
33 - 36	Electricity, Gas, Heat Supply and Water
37 - 41	Information and Communications
42 - 49	Transport and Postal Service
50 - 61	Wholesale and Rental Trade
62 - 67	Finace and Insurance
68 - 70	Real Estate and Goods Rental and Leasing
71 - 74	Scientific Research, Professional and Technical Services
75 - 77	Accommodations, Eating and Drinking Serviecs
78 - 80	Living-related and Personal Services and Amusement Services
81 - 82	Education, Learning Support
83 - 85	Medical, Health Care and Welfare
86 - 87	Compound Services
88 -96	Services, N. E. C.
97 - 98	Government, except elsewhere classified
99	Industries unable to classify

(2) Detail of Manufacturing

SIC code	Name of Sector
9	Food
10	Beverages, tobacco and feed
11	Textile mill products
12	Lumber and wood products, except furniture
13	Furniture and fixtures
14	Pulp, paper and paper products
15	Printing and allied industries
16	Chemical and allied products
17	Petroleum and coal products
18	Plastic products, except otherwise classified
19	Rubber products
20	Leather tanning, leather products and fur skins
21	Ceramic, stone and clay products
22	Iron and steel
23	Non-ferrous metals and products
24	Fabricated metal products
25	General-purpose machinery
26	Production machinery
27	Business oriented machinery
28	Electronic parts, devices and electronic circuits
29	Electrical machinery, equipment and supplies
30	Information and communication electronics equipment
31	Transportation equipment
32	Miscellaneous manufacturing industries

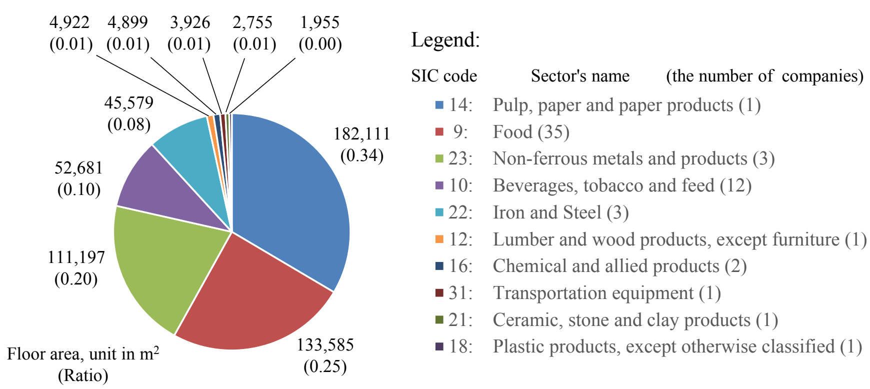


Fig. 6. Floor areas of 60 companies in 10 industrial sectors

IDRiM (2016) 6 (2) ISSN: 2185-8322
DOI10.5595/idrim.2016.0169

2.2 Annual Sales of the 10 Industrial Sectors in 2010

Annual sales are a fundamental index of a private company's activity. The authors researched the data on the annual sales of the 60 companies from 2011-2015 data published by Toyo Keizai Inc., government documents, the companies' official websites, and others sources (see **Appendix A**).

Because the Tohoku tsunami occurred in 2011, economic conditions and other may have changed after the event. Annual sales also may have changed. Thus, it was necessary to collect or estimate the 2010 annual sales for the identified 60 companies.

Annual sales data for 2010 were available for six companies; however, the 2010 data was not available for the remaining 54 companies. Thus, the authors estimated the value using three estimation methods.

The first method was applied to companies ID Nos. 2, 4-9, and 12-36 of manufacture SIC code 9 (see **Appendix A**). The linear relationship between the floor area and the annual sales was estimated based on data from three companies, ID Nos. 3, 10 and 11. In general, information of an amount of annual sales for each company are not always available and are not opened to the public except for major companies. Therefore, we have to estimate the amount of annual sales by using the number of employees, size of factory, capital fund, or the other indexes. But data of employees and capital fund are not available for many companies because of insufficient information. Then the authors adopted data of floor area to estimate the annual sales, because the data of floor area is one of the major indexes related to the size of the factory, and the data can be accessible by using GIS data of ortho-projected satellite image. And the authors introduced a simple assumption of a linear relation between companies of a common SIC code. Annual sales data on 2010 for the three companies were available (Toyo Keizai Inc. 2011; Ryutsukikaku Co., Ltd. 2012) (**Table 3**(1)), and **Fig. 7** (1) was a correlation chart and linear relationship between the floor area and annual sales.

Table 3. Floor area and annual sales

(1) SIC code 9

Company ID no.	Floor area (m^2)	Annual sales in 2010 (billion yen)
3	8,590	14.1
10	13,217	15.0
11	1,148	2.6

(2) SIC code 23

Company ID No.	Floor area (m^2)	Annual sales in 2010 (billion yen)	Annual sales in 2013 (billion yen)
37	7,237	5.5	5.8
38	82,969	N/A	55.9

* N/A : Not available

(3) SIC code 10

Company ID No.	Floor area (m^2)	Annual sales in 2010 (billion yen)	Annual sales in 2014 (billion yen)
40	9,689	N/A	4.6
41	3,066	N/A	0.4
42	2,739	N/A	0.5
43	2,550	N/A	0.4

* N/A : Not available

(4) SIC code 22

Company ID No.	Floor area (m^2)	Annual sales in 2010 (billion yen)	Annual sales in 2014 (billion yen)
52	36,775	16.6 *	23.3 *
53	1,199	N/A **	0.3

* Estimated value (see **Appendix B**) ** N/A : Not available

Arabic numbers in the figure indicate the company ID No. The approximate algorithm adopted was the least-square fitting, and it should be noted that the fitting line needs to pass through the origin because no floor area means no annual sales. The R^2 value equalled to 0.8711, and showed a good fitting result. The annual sales which was a function of the floor area *a* (m^2) was defined by equation (2).

 ISSN: 2185-8322

$$S_{2010}(9) = 0.00129a \tag{2}$$

where $S_Y(x)$ (billion yen) was annual sales for companies which belong to manufacture SIC code x on year Y.

The second method was applied to the company ID Nos. 38-54 of manufacture SIC code 23, 10 and 22. Linear relation between floor area and annual sales were estimated based on 2013 and 2014 data, and corrected from 2013 or 2014 values to 2010 values.

For manufacture SIC code 23, annual sales data on 2010 was available only for company ID No. 37, and it was impossible to estimate a linear relation similar to the equation (2). The value for 2013 was available for two companies, ID Nos. 37 and 38 (**Table 3**(2)) (Agency for Natural Resources and Energy 2014, and Epson Atomix Corporation 2015). **Fig. 7** (2) was a correlation chart and linear relationship between the floor area and annual sales on 2013. It should be noted that the fitting line needs to pass through the origin, and the R^2 value indicated in the figure was calculated under the condition that the line passes through the origin. Unfortunately, there were only two points in the chart, and it was difficult to evaluate the accuracy of the fitting. Although evaluation of accuracy remains to be solved, this relationship was applied to company ID No. 39 because no alternative data was available. Ratio of annual sales for 2010 to 2013 of company ID No. 37 was 0.948, and an assumption was adopted that this value was common to all companies of this manufacturing sector. The annual sales for 2010 was defined by equation (3).

$$S_{2010}(23) = 0.948 \times 0.00067a \tag{3}$$

For manufacture SIC code 10, annual sales data for 2010 was not available, but the values for 2014 was available for four companies, ID Nos. 40-43 (**Table 3**(3)) (Toyo Keizai Inc. 2015, and Agency for Natural Resources and Energy 2015). **Fig. 7** (3) was a correlation chart and linear relationship between the floor area and annual sales for 2014. As with the others, it should be noted that the fitting line needs to pass through the origin. The R^2 value equalled to 0.8497, and showed a good fitting result, and this relationship was applied to companies ID No. 44-51. The Ratio of annual sales for 2010 to 2014 was set to be 0.833, based on a news article for company ID No. 40. The article reported that 'In June 2011, the monthly production level reached 120 % of the past result in June 2010' (Daily Tohoku Shimbun, Inc. 2011a). An assumption was adopted that the condition of the production level was common to all companies of this manufacturing sector and was constant after the tsunami. The annual sales for 2010 was defined by equation (4).

$$S_{2010}(10) = 0.833 \times 0.00041a \tag{4}$$

For manufacture SIC code 22, annual sales data for 2010 was available only for company ID No. 52, and it was impossible to estimate a linear relation similar to equation (2). The value for 2014 was available for two companies, ID Nos. 52 and 53 (**Table 3**(4) and **Appendix B**) (Financial Services Agency 2011 and 2015, and Hachinohe Chamber of Commerce and Industry 2014). **Fig. 7** (4) was a correlation chart and linear relationship between the floor area and annual sales for 2014. The fitting line needs to pass through the origin, and the R^2 value indicated in the figure was calculated under the condition that the line passes through the origin. Unfortunately there were only two points in the chart, and it was difficult to evaluate the accuracy of the fitting. Although evaluation of accuracy remains to be

***IDRiM* (2016) 6 (2)**
DOI10.5595/idrim.2016.0169
ISSN: 2185-8322

solved, this relationship was applied to company ID No. 54 because no alternative data was available. The Ratio of annual sales for 2010 to 2014 of company ID No. 52 was 0.722, and an assumption was adopted that this value was common to all companies of this manufacturing sector. Annual sales for 2010 was defined by equation (5).

$$S_{2010}(22) = 0.722 \times 0.00067a \tag{5}$$

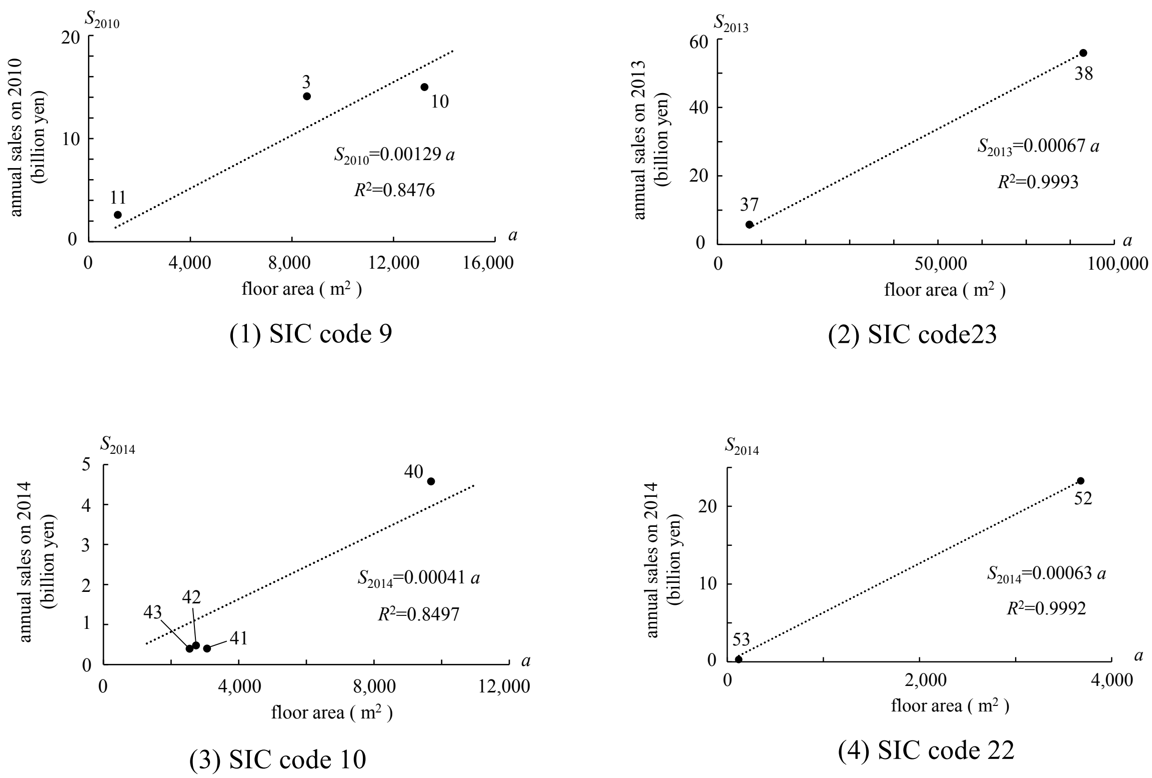


Fig. 7. Floor area and annual sales

The third method was applied to company ID Nos. 1, 55-57, and 60 of manufacture SIC code 14, 12, 16, 31, 21 and 18. This method is similar to that adopted by MLIT, which was discussed in Chapter 1. **Fig. 8** is a flow diagram to estimate annual sales. First, floor area a was converted to the number of employee e using constant coefficient z_1. Subsequently e was converted to annual sales in 2010, S_{2010}, using constant coefficient z_2 and z_3 (Equation (6), (7a) and (7b)):

$$e = z_1(x) \times a \tag{6}$$

$$S_{2010} = z_2(x) \times e \qquad (e =< 300) \tag{7a}$$

$$S_{2010} = z_3(x) \times e \qquad (e > 300) \tag{7b}$$

 ISSN: 2185-8322

The values of z_1-z_3 were provided by the 2010 Census of Manufactures (Aomori prefecture 2010), the 2011 Basic Survey on Small and Medium Enterprises (Small and Medium Enterprise Agency of Japan 2011), and the Basic survey for activities of enterprises (Ministry of Economy, Trade and Industry 2011). **Table 4** shows values of z_1-z_3. The SMEA survey was limited to relatively small and medium enterprises. There was a limitation to apply the results of the survey to large size companies. Meanwhile, that of the METI survey was limited to large enterprises. For this reason we had to sort out companies by the numbers of employees in order to apply Equation (7a) or (7b).

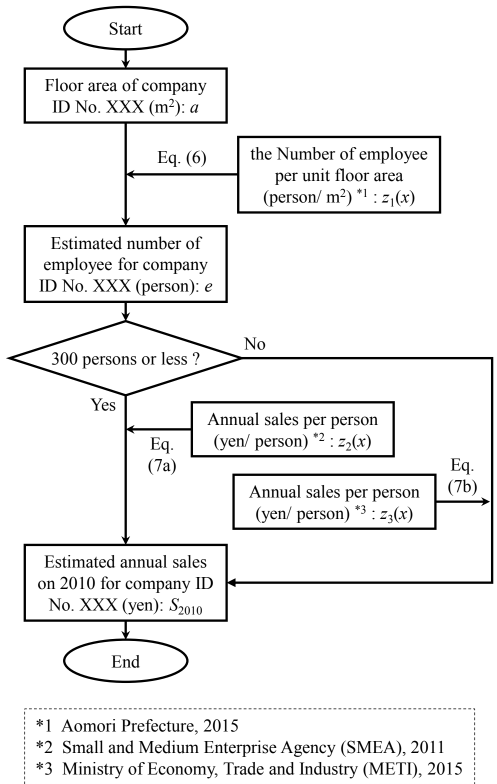


Fig. 8. Floor area and annual sales (SIC code 14, 12, 16, 31, 21 and 18)

Table 4. Constant coefficients z_1-z_3

(1) z_1 based on survey in Aomori Prefecture

SIC code	Employee (person)* : α	Floor area (m²)* : β	$z_1 = \alpha/\beta$ (person/ m²)
14	1,530	302,393	0.0051
12	106	10,389	0.0102
16	440	37,660	0.0117
31	668	28,112	0.0238
21	371	72,193	0.0051
18	883	61,572	0.0143

* Complete survey for 385 companies of 30 or more in employee

(2) z_2 based on survey throughout Japan

SIC code	Annual sales on 2010 (billion yen) : γ	Employee (person) : α	$z_2 = \gamma/\alpha$ (billion yen/ person)
14	3,325	167,848	0.0198
12	1,981	96,029	0.0206
16	6,453	212,069	0.0304
31	6,346	322,278	0.0197
21	3,879	202,264	0.0192
18	5,238	306,793	0.0171

* Sample survey for 1,668,082 companies of 300 or less in employee, or 300 million yen or less in capital stock

Table 4. Constant coefficients z_1-z_3

(3) z_3 based on survey throughout Japan

SIC code	Annual sales on 2010 (billion yen) : γ	Employee (person) : α	$z_3 = \gamma/\alpha$ (billion yen/ person)
14	5,038	102,613	0.0491
12	984	26,743	0.0368
16	31,265	496,546	0.0630
31	55,481	939,580	0.0590
21	4,204	98,045	0.0429
18	7,282	188,884	0.0386

* Sample survey for 37,600 companies of 50 or more in employee, and 30 million yen or more in capital stock (Collection rate: 84.6 %)

Finally, the authors obtained the estimated annual sales in 2010 of 60 companies of the industrial sectors in the inundation area of Hachinohe city due to the 2011 Tohoku tsunami. **Fig. 9** shows the annual sales, and the estimated annual sales in 2010 was 370.6 billion yen in total.

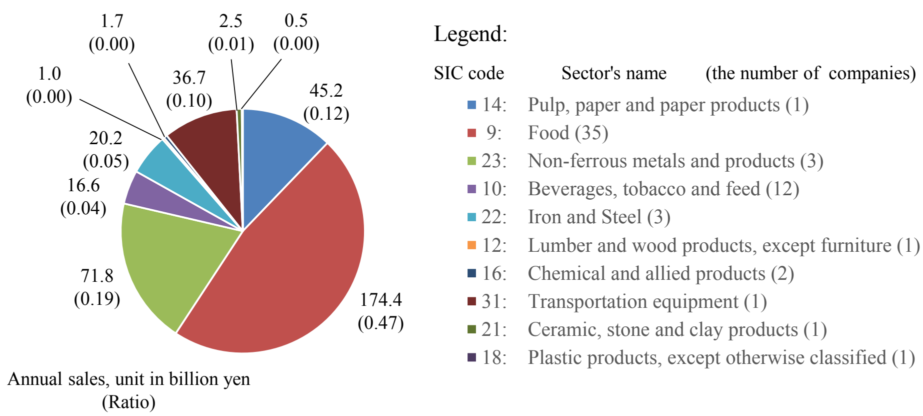


Fig. 9. Annual sales in 2010

3. PRODUCTION CAPACITY CHANGE

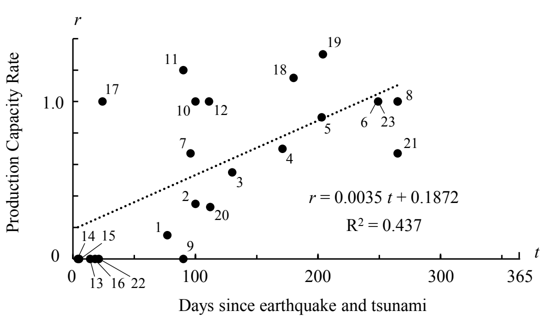
3.1 Production Capacity Rate

The authors researched data on the 60 companies' production capacity. There were two required items: date, and the production capacity rate r. In this study, r was defined as follows: r equal to 0 indicated no production at that time. However, r equal to 1 indicated that production capacity was completely recovered and at the same level as before the tsunami. In some cases, r was more than 1 because of increased production along with capacity investment, increment of extra demand, and other factors.

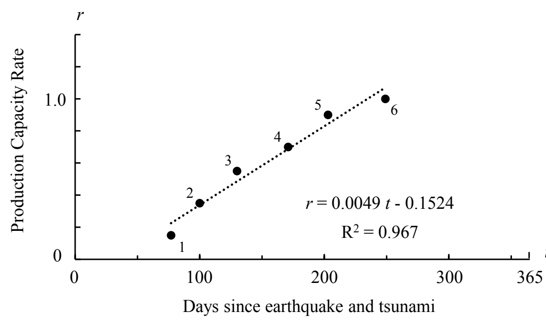
The data was collected from two sources: the first ones were news articles that were provided by a local newspaper company, Daily Tohoku Shimbun Inc. from March 17 to November 16, 2011. The second ones were information posted on websites of companies. A total of 23 data were found for 11 companies from these sources (**Appendix C**). The 23 data were related to the five industrial sectors, SIC codes of 10, 14, 22, 23, and 31; no data were collected for the industrial sectors with SIC codes of 9, 12, 16, 18, and 21.

Fig. 10 (1) to (6) shows the relation between *r* and the days since the earthquake and tsunami for overall data and the five industrial sectors, respectively. The Arabic number in the figure indicates serial numbers of the data, shown in the seventh column of a table in **Appendix C**. The dotted line in each figure reflected results of the least-square fitting algorithm. It was a linear relation between time since the earthquake and tsunami *t* and *r*, and obviously the R^2 values were not good for **Fig. 10** (1), (3), and (5). These values were in the range between 0.208 and 0.437, and were quite low. **Fig. 10** (6) had only two samples, which was not enough for evaluating R^2 value of the fitting line. Despite the difficulties described above, the authors adopted the results in this study because no alternative data was available, and this is an important issue to be addressed in the future. There is also a possible question in assuming that the fitting line was linear, but it can be a quadratic curve, higher-dimensional curve, or step-like shape.

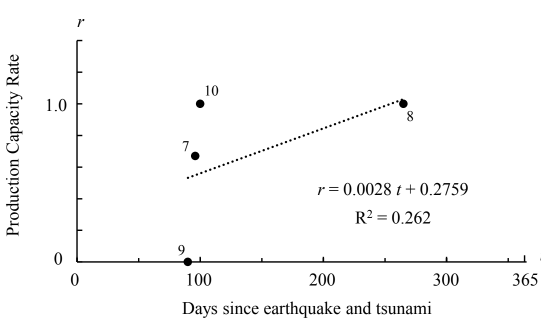
The point where the dotted line and r = 1.0 cross showed the estimated day when the production capacity had recovered completely. According to **Fig. 10** (1) to (6), the estimated days of complete recovery were 232, 235, 259, 95, 245, and 265 days since the earthquake and tsunami. These days were October 29, November 1, November 25, June 14, November 11, and November 30, 2011, respectively.



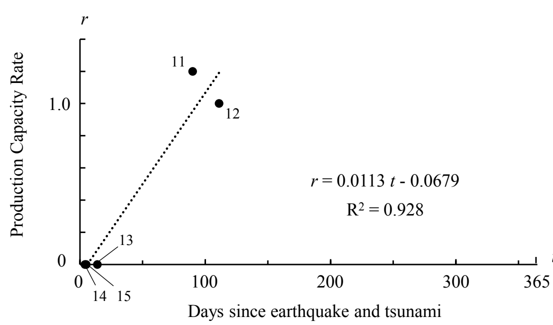
(1) Overall data



(2) Pulp, paper and paper products
(SIC code =14)



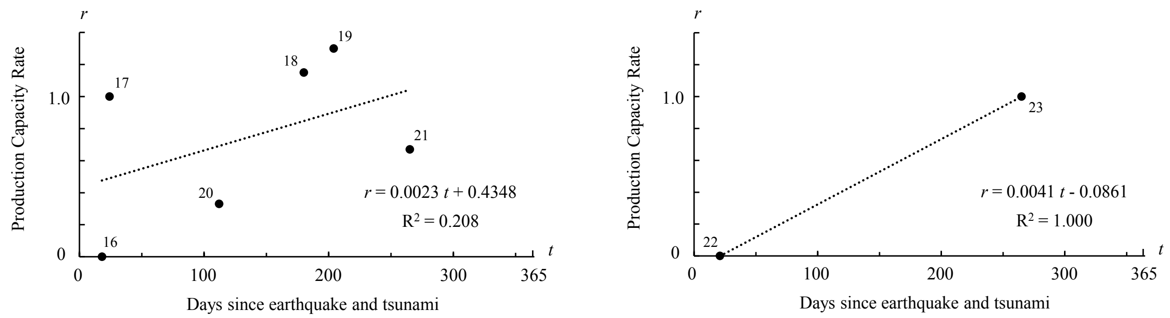
(3) Non-ferrous metals and products
(SIC code =23)



(4) Beverages, tobacco and feed
(SIC code =10)

Fig. 10. Production Capacity

DOI10.5595/idrim.2016.0169



(5) Iron and steel (SIC code =22)

(6) Transportation equipment (SIC code =31)

Fig. 10. Production Capacity

Fig. 11 shows a conceptual diagram for calculation of production capacity change rate $\bar{r}_i(x)$. Area A is flow damage after the earthquake and tsunami, and area B is an actual annual sales. An integrated complement component of r in one year, $\bar{r}_i(x)$, was defined as:

$$\bar{r}_i(x) = \frac{A}{A+B} \tag{8}$$

where the over-line and index i of r indicated complement component, and integrated component of r, respectively. For example, the point of serial number 11 in **Fig. 10** (4) were more than 1.0 in r. It means that the production capacity rate overshot at that time for the company. In the model of **Fig. 11** that we adopted we could not evaluate such an overshoot phenomenon. This point was a limitation of this method, and further study about an evaluation method is necessary. And it can be possible that the production capacity rate for a company continues to be low, less than 1.0, for years. It causes a long term effect, and we have to develop another method to evaluate such a long term effect. As $\bar{r}_i(x)$ is the value for the term from an event to one year after that, there is also a limitation of this method to evaluate the long term effect for more than one year.

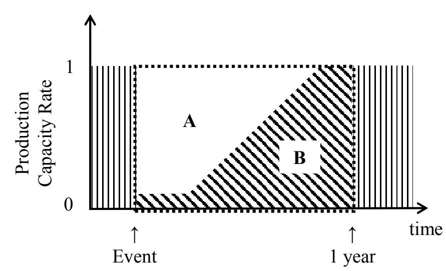


Fig. 11. Conceptual diagram for calculation of $\bar{r}_i(x)$

In **Fig. 10** (1), it was easy to calculate an area of the triangular shape, i.e. an area surrounded by two lines and one axis, such as r = 0.0035 t+0.1872, r=1.0, and t =0. After the calculation, the value was divided by 365, thus giving $\bar{r}_i(x)$ as 0.258. Using this method, **Fig. 10** (2)-(6) gave 0.364, 0.257, 0.138, 0.190, and 0.392.

In general, an operational level of a factory will be affected when demand decreases to a lower level

IDRiM (2016) 6 (2) ISSN: 2185-8322
DOI10.5595/idrim.2016.0169

than the maximum capacity of production. Because of shortage due to the huge earthquake and tsunami, it seemed that the demand always exceeded the production in the affected area. Then we adopted an assumption that companies were operated in the maximum capacity at every moment during the one year after the event. According to the articles which the authors collected, this assumption seemed to be true at least for the companies of SIC code 14, 23, 10, 22 and 31. But there were insufficient information available for the rest of the companies. Further investigation is necessary for the applicability of this assumption.

3.2 Production Capacity Change

The amount of stock damage caused by the earthquake and tsunami was approximately 121.2 billion yen, according to a document announced by the Hachinohe city office at the end of 2011 (Hachinohe City Office 2011).

Evaluating production capacity change $C(x)$ required two values: annual sales in 2010, $S_{2010}(x)$, which was the results from **Section 2.2**, and $\bar{r}_i(x)$ which was the result from **Section 3.1**. Multiplying the two values gave $C(x)$:

$$C(x) = S_{2010}(x) \cdot \bar{r}_i(x) \tag{9}$$

For SIC codes 9, 12, 16, 18, and 21, there was no direct data on $\bar{r}_i(x)$, and thus, the value for the overall case of **Fig. 10** (1) was applied. The failure of $\bar{r}_i(x)$ on these five industrial sectors is an important issue to be addressed in the future.

The estimated flow damage from the production capacity change was approximately 101.9 billion yen in the industrial sectors of the area due to the earthquake and tsunami (**Table 5**). This estimate was equivalent to approximately 84 % of the stock damage in the city.

Table 5. Production Capacity Change in Industrial Sectors of Hachinohe City due to the 2011 Tohoku Tsunami

SIC code	Name of Sector	Annual Sales in 2010 (billion yen)	Production Capacity Change Rate in a year	Production Capacity Change (billion yen)	Ratio
14	Pulp, paper and paper products	45.2	0.364	16.5	0.162
9	Food	174.4	0.258	45.0	0.442
23	Non-ferrous metals and products	71.8	0.257	18.5	0.182
10	Beverages, tobacco and feed	16.6	0.138	2.3	0.023
22	Iron and Steel	20.2	0.190	3.8	0.037
12	Lumber and wood products, except furniture	1.0	0.258	0.3	0.003
16	Chemical and allied products	1.7	0.258	0.4	0.004
31	Transportation equipment	36.7	0.392	14.4	0.141
21	Ceramic, stone and clay products	2.5	0.258	0.6	0.006
18	Plastic products, except otherwise classified	0.5	0.258	0.1	0.001
Total		370.0		101.9	1.000

4. DISCUSSIONS

4.1 Comparison of Production Capacity Charts

Fig. 12 is a comparison chart of Kajitani et al. (2013) and the result of the overall case in **Chapter 3** for production capacity rate. There was a difference between the two, and production capacity change rates $\bar{r}_i(x)$ were approximately 0.059 for Kajitani et al., and 0.258 for overall case in **Chapter 3**. Kajitani et al. used survey data of Nakano et al. (2012) for the 2011 Tohoku earthquake, and the data was collected from companies of Iwate and Miyagi prefectures mainly in areas that were affected by the earthquake, not in the area affected by the tsunami. In the model of Kajitani et al., the production capacity was expressed as a non-linear function of time and the production capacity in the aftermath of the disaster. The non-linear function showed that the recovery speed was accelerated as time advances, because more assets were available as time passed. In contrast, the object area of this study is in the inundation area. Because all data was collected from companies located in Hachinohe city of Iwate prefecture, the object area was a smaller area than the Nakano's study area. And the linear function model was adopted in this study for simplification about the relation between the time and the production capacity rate. These points could cause the difference between Kajitani et al. and the overall case of this study.

Fig. 12 includes the model of MLIT (2005) for business suspension and stagnation, stated in **Chapter 1**. Generally, the dashed-line of MLIT data in the flood area was located in the middle of the two above. The Production capacity change rate $\bar{r}_i(x)$ was 0.124.

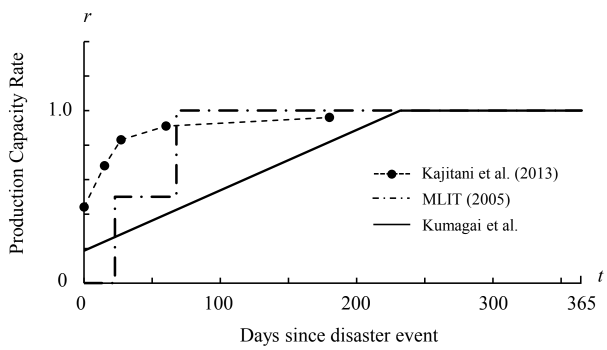


Fig. 12. Comparison of Production Capacity Charts

4.2 Overshoot of Production

In **Fig. 10** (1), the points of serial numbers 11, 18 and 19 were more than 1.0 in *r*. Serial number 11 corresponded to company ID No. 40, and 18 and 19 were for company ID No. 52 (see **Appendix C**). Company ID No. 1 invested in their production facilities in January 2013 (Daily Tohoku Shimbun, Inc. 2013). The sizes of factory of the three companies, ID Nos. 1, 40 and 52, were relatively large, the three companies ranked in the first, eighth, and third position among the 60 companies with respect to floor area, respectively (**Table 6**).

4.3 Discontinuity or Relocation of Facilities

The company ID Nos. 34 and 35 gave up reconstruction by themselves, and whole or a part of the factories were sold (Daily Tohoku Shimbun, Inc. 2011b and 2012a). According to **Table 6**, these were relatively middle size and small factories, the two companies ranked in the thirty-sixth and forty-first position among the 60 companies with respect to floor area, respectively. But the relation between business scale and discontinuity due to tsunami was not clear, because there was no information about business environment of the two companies before 2010.

The company ID Nos. 36 and 37 relocated their factories from coastal areas to inland areas (Daily Tohoku Shimbun, Inc. 2014 and 2012b). The former company was a confectionary manufacturing company and ranked in the forty-second position with respect to floor area, and the latter was a metallic processing manufacturing company and ranked in the thirteenth position. There was no obvious relation between relocation of factories and category of industry or size of floor area.

Table 6. Overshoot, Discontinuity, and Relocation

Category	Company ID	SIC code	Floor area (m^2)	Rank of floor area size
Overshoot of production	1	14	182,111	1
	40	10	9,698	8
	52	22	36,775	3
Discontinuity of factory	34	9	2,548	36
	35	9	2,098	41
Relocation of factory	36	9	2,021	42
	37	23	7,238	13

5. CONCLUSIONS

In this study, production capacity changes were assessed for an industrial area due to the 2011 Tohoku tsunami, which followed the 2011 off the Pacific coast of Tohoku earthquake. The study area was the coastal area of Hachinohe city, which was damaged and inundated by the earthquake and tsunami. Data for the activities of 10 industrial sectors were assembled from published information, newspaper articles, and public announcements.

The results showed that the estimated amount of economic damage was approximately 101.9 billion yen because of the production capacity change in the industrial sectors of the area due to the earthquake and tsunami. The estimated amount was equivalent to approximately 84 % of the amount of the stock damage in the city.

Time-series of production capacity rate in tsunami inundated area showed differences and showed slower recovery of production capacity rate from that of the earthquake affected area.

ACKNOWLEDGMENT

This study was supported by JST/ JICA, SATREPS. The SATREPS Project, Science and Technology Research Partnership for Sustainable Development, is a Japanese government program that promotes international joint research structured as a collaboration between the Japan Science and Technology Agency (JST) and the Japan International Cooperation Agency (JICA). The authors would like to express his gratitude to JST and JICA. The authors would like to thank CONICYT (Chile) for its FONDAP 15110017 and FONDECYT 11140424 grants.

The authors would like to express gratitude to Dr. Ryuichi Shibasaki, head of International Coordination Division, Administrative Coordination Department of National Institute for Land and Infrastructure Management, for his innovative ideas of survey method to collect facts related to production recovery (Technical Note of NILIM No. 677), and for his kind advice to conduct this survey. The authors also would like to acknowledge Mr. Yutaka Kamiyama and Ms. Rumiko Shimizu, former officers of Hachinohe Port and Airport Construction Office, Tohoku Regional Bureau of Ministry of Land, Infrastructure, Transport and Tourism for providing information and assistance to conduct a field survey. The authors would also like to offer special thanks to Dr. Takeshi Suzuki and the other members of Coastal Disaster Prevention Division of NILIM for their kind supports, and Ms. Yoko Nishikawa, DPRI of Kyoto University, for her assistance to conduct the study.

REFERENCES

Agency for Natural Resources and Energy (2014) Census of Manufactures: Document for reduction of and exemption from electric power price surcharge for renewable energy, http://www.enecho.meti.go.jp/category/saving_and_new/saiene/kaitori/nintei_genmei.html (accessed on August 30, 2015)

Agency for Natural Resources and Energy (2015) Census of Manufactures: Document for reduction of and exemption from electric power price surcharge for renewable energy, http://www.enecho.meti.go.jp/category/saving_and_new/saiene/kaitori/nintei_genmei.html (accessed on August 30, 2015)

Aomori Prefecture: Census of Manufactures (2010) http://www.pref.aomori.lg.jp/kensei/tokei/toukei-ichiran.html (accessed on August 30, 2015)

Daily Tohoku Shimbun, Inc. (2011a) Production of feedstuff reaches the maximum in the past, over two million tons, an article in June 9, 2011, http://cgi.daily-tohoku.co.jp/cgi-bin/web_kikaku/m9_shinsai/news/2011/06/ (accessed on May 1, 2013)

Daily Tohoku Shimbun, Inc. (2011b) Tsunami damaged factory gave up reconstruction, an article in August 30, 2011, http://cgi.daily-tohoku.co.jp/cgi-bin/web_kikaku/m9_shinsai/news/2011/08/ (accessed on April 25, 2013)

Daily Tohoku Shimbun, Inc. (2012a) Kick-off of integrated company of three seafood products manufactures in Hachinohe, an article in May 2, 2012, http://cgi.daily-tohoku.co.jp/cgi-bin/web_kikaku/m9_shinsai/news/2012/05/ (accessed on April 26, 2013)

Daily Tohoku Shimbun, Inc. (2012b) Challenges for comeback, an article in March 6, 2012, http://cgi.daily-tohoku.co.jp/cgi-bin/web_kikaku/m9_shinsai/ootunami/saiki_02.htm (accessed on April 24, 2013)

Daily Tohoku Shimbun, Inc. (2013) Production was recovered and in the same level as before the disaster, an article in January 11, 2013, http://cgi.daily-tohoku.co.jp/cgi-bin/web_kikaku/m9_shinsai/news/2013/01/ (accessed on May 1, 2013)

Daily Tohoku Shimbun, Inc. (2014) Dreams for tomorrow, earthquake disaster sufferers at the present, an article in March 9, 2014, http://www.daily-tohoku.co.jp/m9_shinsai/kikaku.kikaku2014/asuenonegai/ (accessed on June 22, 2015)

Epson Atomix Corporation (2015) http://www.atmix.co.jp/ (accessed on June 30, 2015)

Financial Services Agency (2011) Asset securities report, Electric Disclosure for Investors' Network (EDINET), E01292, http://disclosure.edinet-fsa.go.jp/ (accessed on August 30, 2015)

Financial Services Agency (2015) Asset securities report, Electric Disclosure for Investors' Network (EDINET), E01292, http://disclosure.edinet-fsa.go.jp/ (accessed on August 30, 2015)

Hachinohe Chamber of Commerce and Industry (2014) Matching guidebook for technology enterprises of Hachinohe pruducts, http://www.8cci.or.jp/matching_guidebook/matching_guidebook.pdf, pp. 16

(accessed on August 30, 2015)

Hachinohe City Office (2011) Summary Table of the Damage, Documents of the Headquarters for Disaster Control, https://www.city.hachinohe.aomori.jp/index.cfm/26,39551,84,222,html (accessed on August 30, 2015)

Haraguchi T. and Iwamatsu A. (2011) Detailed Maps of the Impacts of the 2011 Japan Tsunami, Vol. 1: Aomori, Iwate and Miyagi prefectures, *Kokon-Shoin Publishers Ltd.*, pp. 9-12.

Kajitani Y., Tatano H. and Yoshimura Y. (2013) Estimation of Production Capacity Losses in Industrial Sectors Due to a Large-scale Disaster: A Case of the Great East Japan Earthquake, *Journal of Natural Disaster Science*, 31(4): 283-304.

Mas E., Koshimura S., Suppasri A., Matsuoka M., Yoshii T., Jimenes C., Yamazaki F. and Imamura F. (2012) Developing Tsunami fragility curves using remote sensing and survey data of the 2011 Chilean Tsunami in Dichato, *Natural Hazards and Earth System Sciences*, 12: 2689-2697.

Ministry of Economy, Trade and Industry (2011) the Basic survey for activities of enterprises, http://www.meti.go.jp/statistics/tyo/kikatu/result-2/h23data.html (accessed on August 30, 2015)

Ministry of Internal Affairs and Communications (2013) the Standard Industrial Classification of All Economic Activities, Rev. 13, http://www.soumu.go.jp/ toukei_toukatsu/index/seido/sangyo/ (accessed on August 30, 2015)

Ministry of Land, Infrastructure, Transport and Tourism (2005) The technical manual of cost-benefit analysis for flood control measures (tentative), pp. 56-57.

Nakano K., Kajitani Y., Tagashira N., Hitomi K. and Tatano H. (2012): Survey for Economic Impact and Business Recovery of the Great East Japan Earthquake, CRIEPI Research Report No. Y11022, Central Research Institute of Electric Power Industry, 41 p.

Ryutsukikaku Co., Ltd. (2012) Yearbook of daily dishes, boxed lunches, and food services market, pp. 100.

Small and Medium Enterprise Agency (2011) the 2011 Basic Survey on Small and Medium Enterprises, http://www.e-stat.go.jp/SG1/estat/List.do?lid=000001093273 (accessed on August 30, 2015)

The 2011 Tohoku Earthquake Tsunami Joint Survey Group (2012) The 2011 off the Pacific coast of Tohoku Earthquake Tsunami Information, http://www.coastal.jp/tsunami2011/ (accessed on August 30, 2015)

Toyo Keizai Inc. (2011) Unlisted companies, Issue for the Second half of fiscal year 2011, ISBN 978-4-492- 97823-8, CD-ROM.

Toyo Keizai Inc. (2015) Unlisted companies, Issue for the Second half of fiscal year 2015, ISBN 978-4-492- 97831-3, CD-ROM

IDRiM (2016) 6 (2)
DOI10.5595/idrim.2016.0169
ISSN: 2185-8322

Appendix A. Annual sales of the 60 companies

Table A.1. Annual sales of the 60 companies

SIC code	Company's ID	Annual sales (billion yen)	Year	Data source/ sources
14	1	N/A	-	-
9	2	4.0	2014	Document published by Government [1)]
	3	13.4 - 14.8	2007- 2014	Toyo Keizai Inc. [2)-6)]
	4	5.5	2014	Company's website [7)]
	5	2.0	2012	Company's website [8)]
	6	0.1	2012-2014	Document published by the Government [9)-11)]
	7	5.8	2014	Websites of the local news company or others [12)]
	8	0.9	2014	Websites of the local news company or others [13)]
	9	4.6	2013	Websites of the local news company or others [14)]
	10	14.1 - 15.6	2010 - 2014	Toyo Keizai Inc. [2)-6)]
	11	2.0	2008	Ryutsukikaku Co., Ltd. [15)]
	12-36	N/A	-	-
23	37	5.5 - 6.4	2010 - 2013	Toyo Keizai Inc. [2)-3)] Websites of the local news company or others [16)]
	38	45.9 - 55.9	2012 - 2014	Document published by the Government [9)-11)]
	39	N/A	-	-
10	40	4.4 - 4.6	2012 - 2014	Toyo Keizai Inc. [4)-6)]
	41	0.4	2014	Document published by the Government [10)]
	42	0.5	2014	Toyo Keizai Inc. [6)]
	43	0.4	2012 - 2014	Toyo Keizai Inc. [4)-6)]
	44 - 51	N/A	-	-
22	52	40.0 - 53.4	2011 - 2014	Document published by the Government [9)-11), 17)]
	53	0.3	2014	Websites of the local news company or others [18)]
	54	N/A	-	-
12	55	N/A	-	-
16	56	0.4 - 0.6	2012 - 2014	Document published by the Government [9)-11)]
	57	N/A	-	-
31	58	14.7 - 36.7	2006 - 2014	Toyo Keizai Inc. [2)-6)]
21	59	2.0 - 2.7	2006 - 2012	Company's website [19)]
18	60	N/A	-	-

* N/A : Not available

Reference for **Table A.1**

1) Ministry of Agriculture, Forestry and Fisheries (2015) Collection of Leading-edge Cases on Site, http://www.maff.go.jp/j/kanbo/saisei/jikou_honbu/, Aomori Prefecture Part 1, pp. 8. (accessed on July 28, 2015)

2) Toyo Keizai Inc. (2011) Unlisted companies, Issue for the Second half of fiscal year 2011, ISBN 978-4-492- 97823-8, CD-ROM.

3) Toyo Keizai Inc. (2012) Unlisted companies, Issue for the Second half of fiscal year 2012, ISBN 978-4-492- 97825-2, CD-ROM.

4) Toyo Keizai Inc. (2013) Unlisted companies, Issue for the Second half of fiscal year 2013, ISBN 978-4-492- 97827-6, CD-ROM.

5) Toyo Keizai Inc. (2014) Unlisted companies, Issue for the Second half of fiscal year 2014, ISBN 978-4-492- 97829-0, CD-ROM.

6) Toyo Keizai Inc. (2015) Unlisted companies, Issue for the Second half of fiscal year 2015, ISBN 978-4-492- 97831-3, CD-ROM.

7) Marunushi Co., Ltd. (2015) http://marunushi.co.jp/company/ (accessed on June 24, 2015)

8) Zengyoren Hachinohe Shokuhin Corp. (2015) http://www.jfhc.jf-net.jp/page_01-02.html (accessed on July 28, 2015)

9) Agency for Natural Resources and Energy (2013) Census of Manufactures: Document for reduction of and exemption from electric power price surcharge for renewable energy, http://www.enecho.meti.go.jp/category/saving_and_new/saiene/kaitori/nintei_genmei.html (accessed on August 30, 2015)

10) Agency for Natural Resources and Energy (2014) Census of Manufactures: Document for reduction of and exemption from electric power price surcharge for renewable energy, http://www.enecho.meti.go.jp/category/saving_and_new/saiene/kaitori/nintei_genmei.html (accessed on August 30, 2015)

11) Agency for Natural Resources and Energy (2015) Census of Manufactures: Document for reduction of and exemption from electric power price surcharge for renewable energy, http://www.enecho.meti.go.jp/category/saving_and_new/saiene/kaitori/nintei_genmei.html (accessed on August 30, 2015)

12) Recruit Career Co., Ltd. (2015) https://job.rikunabi.com/2016/company/top/r420600087/ (accessed on July 29, 2015)

13) The To-o Nippo Press Co.,Ltd. (2015) http://www.toonippo.co.jp/news_too/nto2015/20150626002984.asp (accessed on July 29, 2015)

14) Careport-Sendai (2015) http://www.tansyoku.com/company/data.html (accessed on July 29, 2015)

15) Ryutsukikaku Co., Ltd. (2010) Yearbook of daily dishes, boxed lunches, and food services market, pp. 104.

16) Epson Atomix Corporation (2015) http://www.atmix.co.jp/ (accessed on June 30, 2015)

17) Agency for Natural Resources and Energy (2012) Census of Manufactures: Document for reduction of and exemption from electric power price surcharge for renewable energy, http://www.enecho.meti.go.jp/category/saving_and_new/saiene/kaitori/nintei_genmei.html (accessed on August 30, 2015)

18) Hachinohe Chamber of Commerce and Industry (2014) Matching guidebook for technology enterprises of Hachinohe products, http://www.8cci.or.jp/matching_guidebook/matching_guidebook.pdf, pp. 16.

19) Hyogo Clay Co., Ltd. (2015) http://www.hyogoclay.co.jp/company/ (accessed on June 24, 2015)

IDRiM (2016) 6 (2) ISSN: 2185-8322
DOI10.5595/idrim.2016.0169

Appendix B. Annual sales of Company ID No. 52

The annual sales on 2014 of Company ID No. 52 was estimated using documents provided by Financial Services Agency[1)-2)]. The company had two factories in Hachinohe and the other city, and one office. Estimated annual sales for the Hachinohe factory was calculated based on the numbers of employee in the factories and office. Results of the calculation were 12.1 and 16.7 billion yen in 2010 and 2014.

In the site of the Hachinohe factory, there were a sister company, and its annual sales was 4.4 [3)] and 6.6 [4)] billion yen in 2010 and 2014.

Finally estimated annual sales of company ID No. 52 were 16.6 and 23.3 billion yen.

Reference for **Appendix B.**

1) Financial Services Agency (2011) Asset securities report, Electric Disclosure for Investors' Network (EDINET), E01292, http://disclosure.edinet-fsa.go.jp/ (accessed on August 30, 2015)

2) Financial Services Agency (2015) Asset securities report, Electric Disclosure for Investors' Network (EDINET), E01292, http://disclosure.edinet-fsa.go.jp/ (accessed on August 30, 2015)

3) Toyo Keizai Inc. (2011) Unlisted companies, Issue for the Second half of fiscal year 2011, ISBN 978-4-492- 97823-8, CD-ROM.

4) Toyo Keizai Inc. (2015) Unlisted companies, Issue for the Second half of fiscal year 2015, ISBN 978-4-492- 97831-3, CD-ROM.

***IDRiM* (2016) 6 (2)** **ISSN: 2185-8322**
DOI10.5595/idrim.2016.0169

Appendix C. Production capacity rate *r* and data sources

Table C.1. Production capacity rate r and data sources

SIC code	Company ID No.	Date (MM-DD-YYYY)	Days since tsunami	Production capacity rate *r*	Data source (Date of publishing)	Sequential serial number
14	1	05-27-2011	77	0.15	DTS (05-28-2011)	1
		06-19-2011	100	0.35	DTS (06-21-2011)	2
		07-19-2011	130	0.55	DTS (07-21-2011)	3
		08-29-2011	171	0.70	DTS (08-28-2011)	4
		09-30-2011	203	0.90	DTS (07-21-2011)	5
		11-15-2011	249	1.00	DTS (11-16-2011)	6
23	38	06-15-2011	96	0.67	DTS (07-13-2015)	7
		12-01-2011	265	1.00	DTS (07-13-2015)	8
	39	06-09-2011	90	0.00	DTS (06-12-2011)	9
		06-19-2011	100	1.00	DTS (06-12-2011)	10
10	40	06-09-2011	90	1.20	DTS (06-09-2011)	11
	44	06-30-2011	111	1.00	DTS (05-23-2011)	12
	46	03-25-2011	14	0.00	Document posted on website of company (03-25-2011) http://www.co-op.co.jp/	13
	48	03-15-2011	4	0.00	DTS (03-17-2011)	14
	49	03-16-2011	5	0.00	DTS (03-17-2011)	15
22	52	03-29-2011	18	0.00	DTS (04-05-2011)	16
		04-04-2011	24	1.00	DTS (04-05-2011)	17
		09-07-2011	180	1.15	DTS (09-07-2011)	18
		10-01-2011	204	1.30	DTS (09-07-2011)	19
	53	07-01-2011	112	0.33	Information posted on website of company http://kitanihon-mekki.co.jp/ (accessed on August 30, 2015)	20
		12-01-2011	265	0.67	Information posted on website of company http://kitanihon-mekki.co.jp/ (accessed on August 30, 2015)	21
31	58	04-01-2011	21	0.00	Information magazine of the Ports and Harbours Association of Japan, Vol. 91, April, pp. 36-37, 2014.	22
		12-01-2011	265	1.00	Information magazine of the Ports and Harbours Association of Japan, Vol. 91, April, pp. 36-37, 2014.	23

*DTS: News article of Daily Tohoku Shimbun, Inc., http://cgi.daily-tohoku,co.jp/cgi-bin/web_kikaku/m9_shinsai/news/ (accessed on April 24, 2013.)